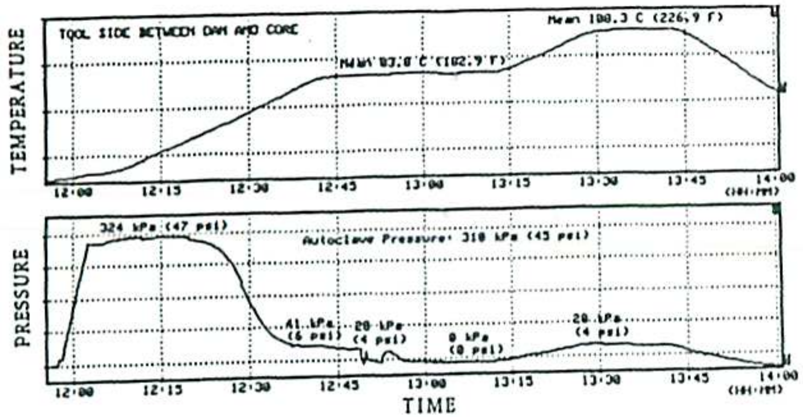

Figure 6. Resin Pressure Readings for Honeycomb Sandwich Structure

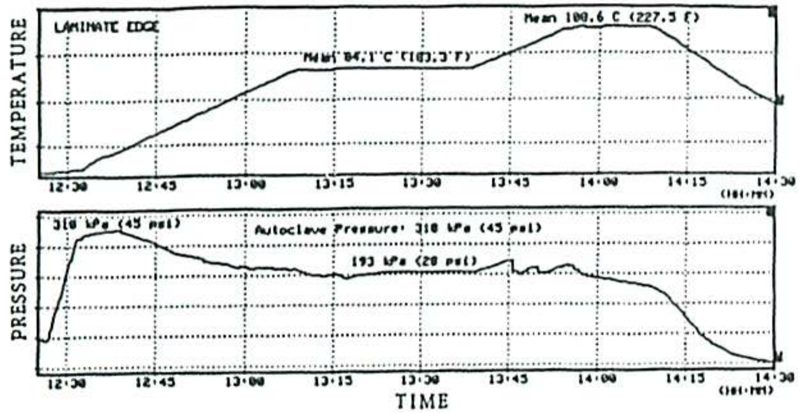

Figure 7. Resin Pressure Readings for Edge Band

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FABRICATION AND MECHANICAL PROPERTIES OF BRAIDED COMPOSITE TRUSS JOINT

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ABSTRACT

T-shape braided graphite/epoxy composite truss joints were fabricated by applying the conventional braiding technique and introducing three-dimensional taking up mechanism. This braided construction could be fabricated without cutting the fibers. As braided fabric could be inserted the longitudinal fiber (middle-end-fiber), this fabric was similar to triaxial woven fabrics. The T-shape composite truss joints that had braided construction with the middle-end-fibers were also fabricated. The mechanical properties of these T-shape composite truss joints were evaluated. It was clear that the middle-end-fibers were effective to improve the mechanical properties of T-shape braided composite truss joint.

KEYWORD: Braided Construction; Fiber Reinforcements; Composites; T-Shape; Truss Joint.

1. INTRODUCTION

Composite materials has been used widely in both primary and secondary load bearing structural components. However conventional 2-D laminates have very poor interlamina strength, and as a result have limit in their applications and utilizations for complex shaped structural parts. In order to overcome this limitation, the 3-D weaving technique to realize the concept of near-net-shape has been studied$^{1)-3)}$. These technique involves some difficulties (e.g. complicated machine, High cost) to produce composite materials with complex shape. Also, it is said that, the concept of near-net-shape can be realize by braiding technique$^{4)-6)}$. Braiding machine consists of simple equipments. In our early studies ,we have adopted the simple structures such as the tube and flat bar as basic shape elements of braided construction and have discussed the mechanical properties of braided tube and flat bar$^{7)-10)}$. It has been clear from these results that a braided structure has some advantages in comparison with other reinforcement configurations. Our basic concept has been that reinforcing fibers continuously have to be oriented without cutting them, in order to obtain composite materials with superior mechanical properties.

In this study, a T-shape composite truss joint was fabricated by using the braiding technique. The three-dimensional taking up mechanism was introduced into the conventional braiding technique. The T-shape truss joint with a braided construction was fabricated, and its mechanical properties was evaluated. Moreover, in order to improve the strength, T-shape braided truss joints inserted the longitudinal fibers (middle-end-fibers) were discussed.

2. CONCEPT OF BRAIDING TECHNIQUE

Figure 1 shows a schematic diagram of tubular braid and its conventional braiding machine. The fiber bundles are supplied from the spindles which move on the course. The tubular braid is formed on a mandrel according to intercross of the moving spindles and taking up the mandrel. In general, the motion of the mandrel is only one direction, when the tubular braid is fabricated.

Braided construction with a complex shape can not be fabricated in this braiding technique. However, if three-dimensional motion of the mandrel is possible, as shown in Figure 2, braided construction with a complex shape can be fabricated without cutting fiber bundles. In addition, it can be braided by a series of process.

For example, considering a member as T-shape truss joint, it is necessary to move the mandrel three-dimensionally.

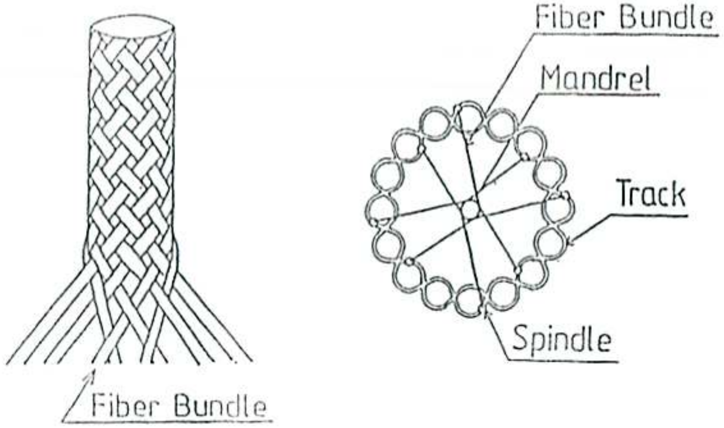

Figure 1 Schematic diagram of the tubular braid and the track.

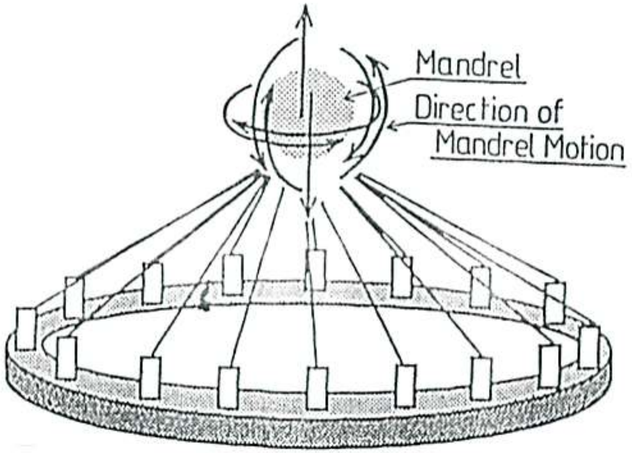

Figure 2 Concept of new braiding mechanism.

Figure 3 shows a new braiding machine for fabricating T-shape tubular braid. This braiding machine was composed of three dimensional taking up mechanism and the conventional tubular braiding machine. The mandrel could be moved to vertical direction against the course plate as well as the conventional braiding machine. However, in the new braiding machine the mandrel could turn by new mechanism. The motion of the mandrel above two direction was possible by this mechanism, so T-shape tubular braid could be fabricated. The fiber bundles passed on the guide, as shown in this Figure, to supply to the mandrel from vertical direction. And turn of the mandrel was necessary to fabricate T-shape braided truss joint.

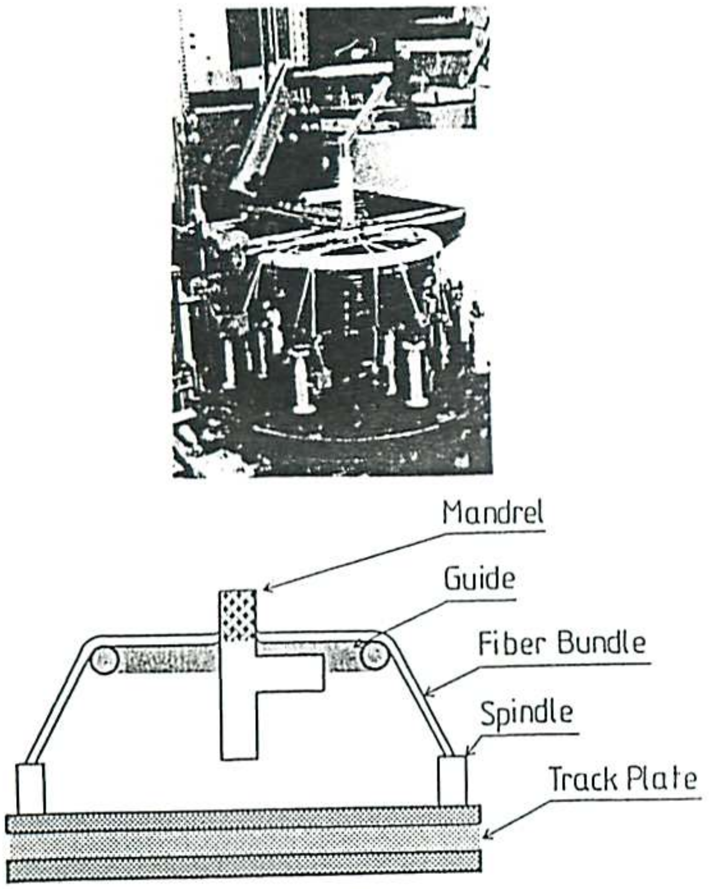

Figure 3 Outside view and schematic diagram of new braiding machine for fabricating T-shape tubular braid.

Figure 4 illustrates a cycle of braiding process of T-shape tubular braiding truss joint preform. In this Figure, the arrows on side of the mandrel showed the moving direction of the mandrel. Braided fabric with two layers was obtained in a cycle of process. Vertical motion and turn of the T-shape mandrel were repeated during braiding process. Braiding process was started from the point A. As braided fabric had reached the point D, then the mandrel turned, and fiber bundles were braided from the point D to the point B. After the braided fabric had reached the point B, the fiber bundles were reversed and were braided to the point D. When the braided fabric reached the point D, the mandrel turned again. Finally, the braided fabric was formed from the point D to the point C, and the point C to the point A.

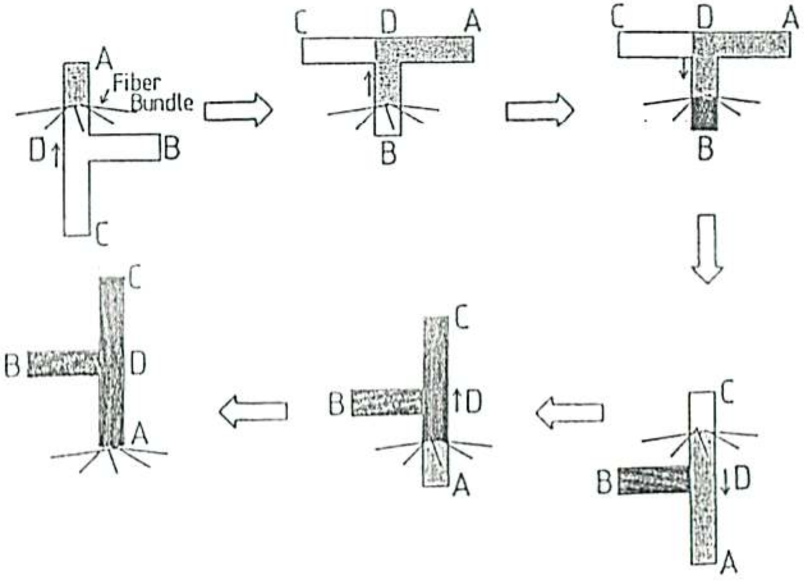

Figure 4 Braiding process of T-shape braided truss joint preform.

Figure 5 shows a schematic diagram of T-shape truss joint preform. All fiber bundles continuously oriented at the joining part D in the T-shape braid.

Furthermore, the braided fabric could be inserted the longitudinal fibers (middle-end-fibers) , so the structure of this fabric was similar to triaxial woven fabric. The middle-end-fibers were inserted simultaneously during braiding process. It was possible to change the number of the middle-end-fibers.

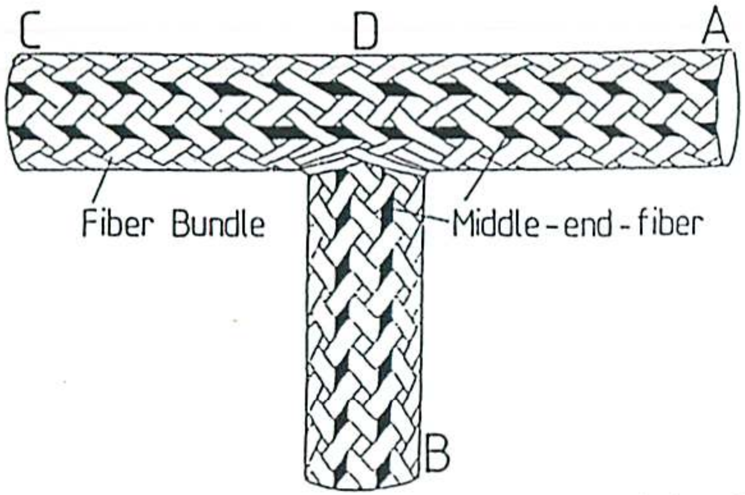

Figure 5 Schematic diagram of T-shape tubular braided preform.

3. SPECIMENS AND TESTING METHOD

In this study, the fiber bundle was carbon fiber roving consisting of 12,000 and 3,000 filaments. (T300, Toray Industry Co., Ltd.) Matrix was epoxy resin (EPIKOTE 828, Yuka Shell Epoxy Kabushikigaisha) and curing agent was amin system hardener(KC1118, Koei Chemical Co., Ltd.). Two cycles of the above mentioned braiding process were performed, so the preform was four layers. In the preform the braiding angle which represents the fiber orientation angle to the longitudinal direction of the tube was about 65 degree.

The resin impregnation was carried out in a vacuum oven for 10 minutes. The dry of resin was conducted at room temperature for 5 hours until B-stage. The resin was cured by Autoclave at 7 kgf/cm^2 pressure, and 100oC temperature. Finally, the post curing was performed at 100oC for 8 hours.

Figure 6 shows outside view of T-shape truss joint composite. The fiber volume fraction was about 42%.

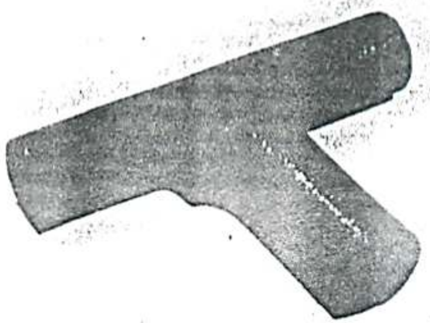

Figure 6 Outside view of T-shape truss joint composite.

The list of specimens is summarized in Table 1. The positions of middle-end-fibers are indicated in Figure 7. There were six kinds of the specimens. In all braided specimens, fiber bundles which contained 12,000 filaments were used as braiding fiber bundle. The specimens which were indicated by sign BM, BMT4, BMT8 and BMS16 had 16 braiding fiber bundles, and the specimen BLT8 had 8 braiding fiber bundles. Furthermore, the specimens BMT4, BMT8, BLT8 and BMS16 had 4, 8, 8 and 16 middle-end-fibers respectively. The middle-end-fibers of the specimen BMS16 were the fiber bundles of 3,000 filaments, and those of other specimens were used fiber bundles of 12,000 filaments. The specimen CL was fabricated by winding the cloth tape.

Figure 8 shows the dimension of the specimens. The length of A-C was 150mm and the length from center of tube A-C to B was 75mm.

Table 1 List of specimens.

	BM	BMT4	BMT8	BMS16	BLT8	CL
Reinforcement configuration	Braid	Braid	Braid	Braid	Braid	Cloth
Number of braiding fiber bundles	16 (12.000)	16 (12.000)	16 (12.000)	16 (12.000)	8 (12.000)	(3.000)
Number of Middle-end-fiber bundles	0	4 (12.000)	8 (12.000)	16 (3.000)	8 (12.000)	- -
Diameter Inner[Di](mm)	26.0					
Diameter Outer[Do](mm)	30.8	31.3	33.0	30.7	33.8	29.7

( ) : Number of filaments in a fiber bundle

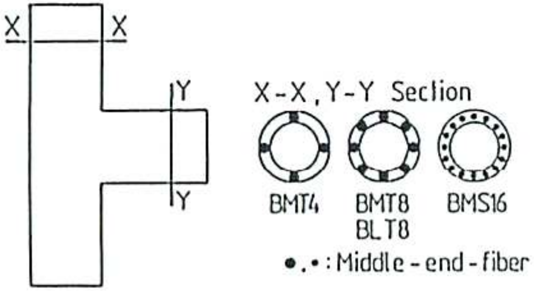

Figure 7 Position of the middle-end-fibers.

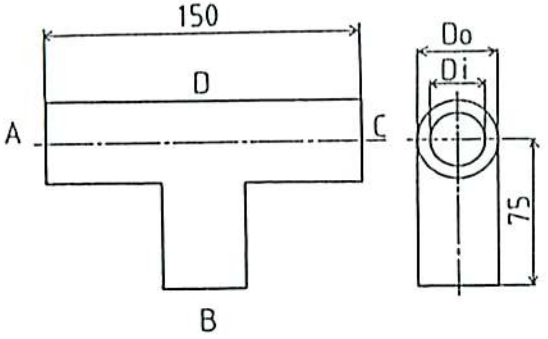

Figure 8 Dimension of specimen.

Figure 9 shows the testing method. This test was the cantilever type bending test. The specimen was fixed on a jig at the point A and C. And the steel bar was inserted to B part of the specimen. The distance from the center of tube A-C to the load applied point was 100mm. The test was conducted by Instron Universal Testing Machine (Type 4206) at cross head speeds of 2 mm/min.

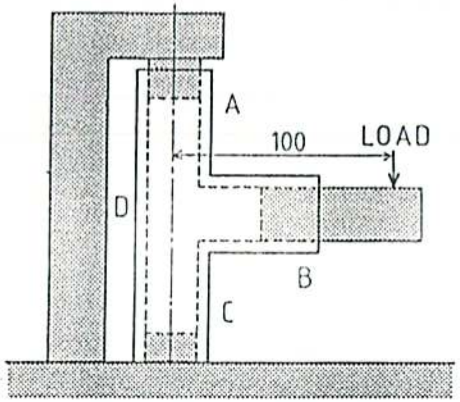

Figure 9 Testing method.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The load-displacement curves of specimen BM and CL are shown in Figure 10. In both cases , the slopes of the curves became small as the displacement increased. The slopes of curve of specimen BM was larger than that of specimen CL. Maximum load of specimen BM was higher than that of specimen CL. Figure 11 shows fracture aspects of specimens BM and CL after the test. In the case of specimens CL, the ultimate failure occurred at the corner of tension side. On the other hand, in the case of specimen BM, it also occurred at tension side, however that positions apart from the corner. It was considered that the continuity of the fiber bundles had effect on improvement of the stiffness and the maximum load of specimen BM, because all fiber bundles continuously oriented in specimen BM, and did not in specimen CL. Braiding construction which had reinforcements oriented continuously provided with the high stiffness and high strength in T-shape composite truss joint.

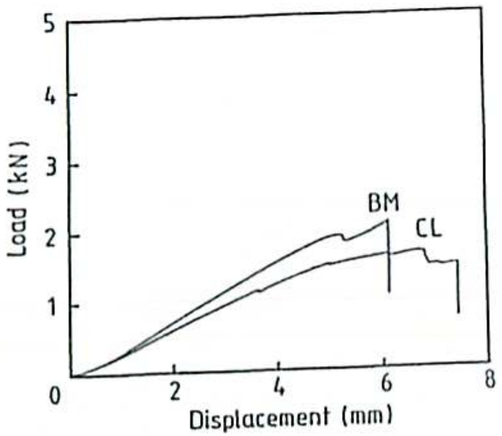

Figure 10 Load-displacement curves of specimen BM and CL.

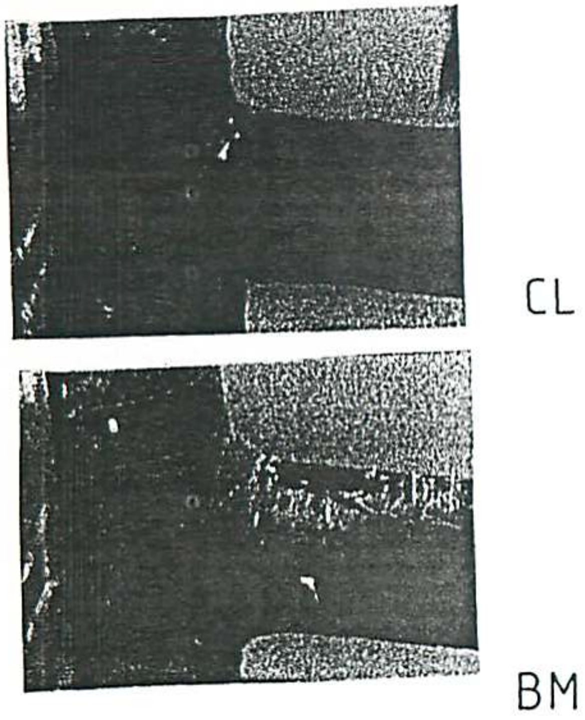

Figure 11 Fracture aspects of specimen BM and CL.

Figure 12 shows load-displacement curves of specimens which had the middle-end-fibers and specimen BM. The slopes of curves of specimen which had the middle-end-fibers were larger than that of specimen BM.

Figure 13 shows the maximum load of specimens with braided construction. The maximum load of T-shape braided truss joint increased by inserting the middle-end-fibers.

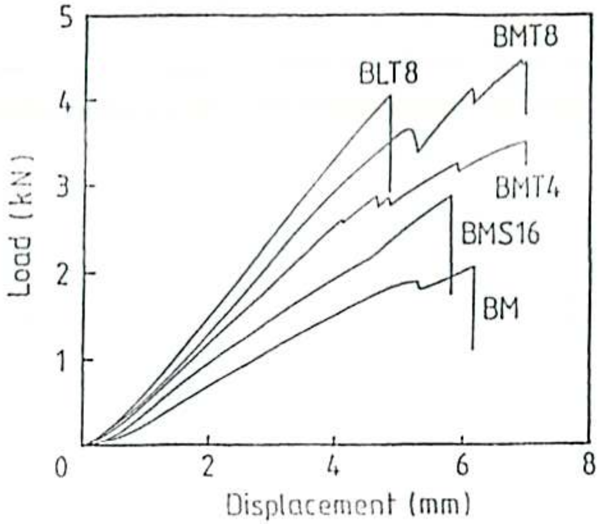

Figure 12 Load-displacement curves .
(BM,BMT4,BMT8,BLT8 and BMS16)

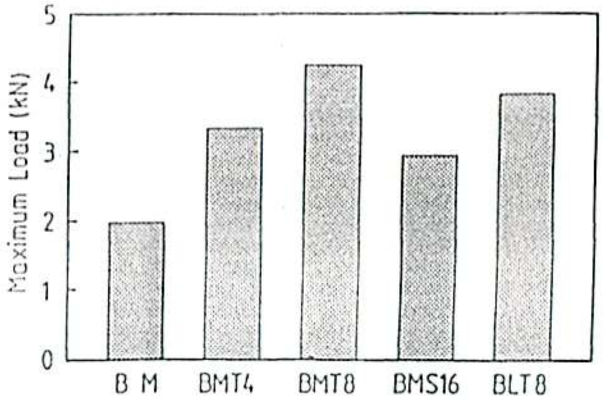

Figure 13 Maximum load. (BM,BMT4,BMT8,BLT8 and BMS16)

As compared with the mechanical properties among specimens BM, BMT4 and BMT8, slope of the curve in specimen BM was the smallest and that of specimen BMT8 was the largest, in Figure 12. The maximum load of specimen BMT4 was higher about 1.7 times than specimen BM, and the specimen BMT8 was higher about 2.2 times than specimen BM,in Figure 13. It was clear that the middle-end-fiber was effective to raise mechanical properties, the stiffness and the maximum load, of T-shape composite truss joint.

As specimen BMT4 was compared with specimen BMS16, the total number of filaments which were used as the middle-end-fiber was equal. In Figure 12 the slope of curve in specimen BMS16 was smaller than that of specimen BMT4. The maximum load of BMS16 was smaller than that of specimen BMT4 in Figure 13. The number of filaments of the middle-end-fiber , in specimen BMS16, was fewer than that in specimen BMT4 on the position where the highest tensile stress occurred.

Specimen BLT8 was compared with the specimen BM and BMT8. The number of fiber bundles in specimen BLT8 was equal to that in specimen BM. The braiding structure in specimen BLT8 consisted of 8 middle-end-fibers and 8 braiding fiber bundles. The maximum load of specimen BLT8 was higher than the specimen BM, and was nearly the same that of specimen BMT8.

It is possible to control stiffness and strength of the braided T-shape truss joint by inserting the middle-end-fibers.

5. APPLICATION

Figure 14 and 15 show the triaxial truss joint, the front fork of bicycle, respectively. These were fabricated by using new braiding technique which was developed in this study these braided constructions were also fabricated without cutting fibers according to our concept. Braided fabrics with more complex shape may be fabricated by applying to this braiding technique.

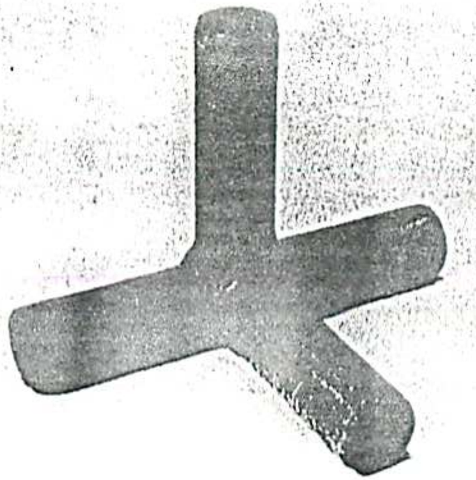

Figure 14 Triaxial truss joint.

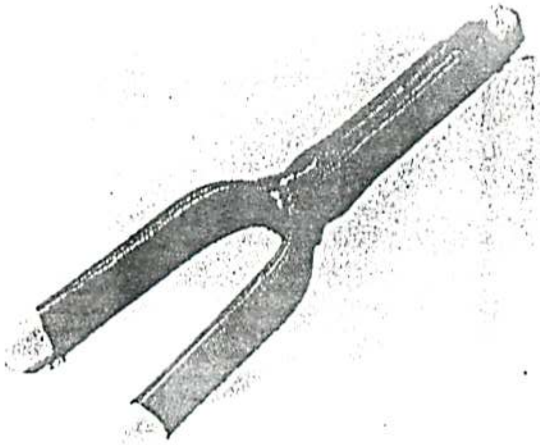

Figure 15 Front fork.

6. CONCLUSION

In this study, we fabricated the T-shape composite truss joints with braided construction and discussed their properties.

The T-shape composite truss joint could be easily fabricated by introducing new taking up mechanism into conventional tubular braiding machine. The T-shape braided truss joint had higher strength as compared with truss joint reinforced with cloth tape. The middle-end-fibers were effective for raising the strength of the braided T-shape truss joint. It was clear that braiding construction could provide with T-shape composite truss joint which had superior mechanical properties. It is possible to control the braided T-shape truss joint by inserting the middle-end-fibers.

Braided fabrics with more complex shape may be fabricated by applying to this braiding technique.

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